Performance Evaluation of Space Networks

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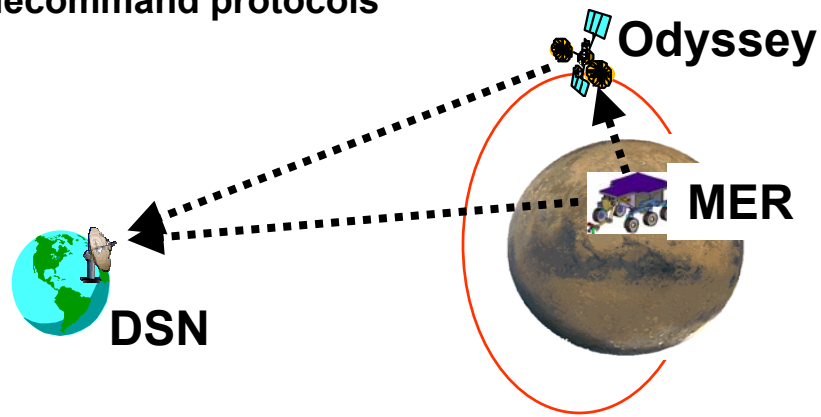
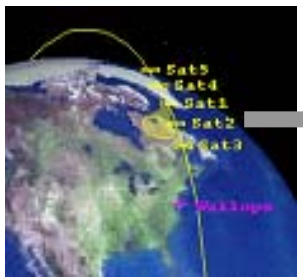
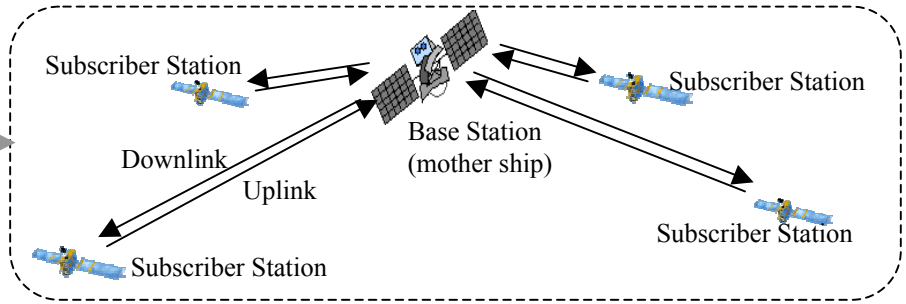
Background

- **Performance evaluation tool is under ongoing development to support Interplanetary Network Directorate (IND), Mars Exploration Program, and Space Communications Project**
- **Focus of tool is relay network communications for space missions**
- **Illustrative scenario used to describe tool:**
  - **Context: MER-Odyssey-DSN relay operation using CCSDS Proximity-1 Space Link Protocol, Packet Telemetry & Packet Telecommand protocols**
  - **Duration: 10-day operation**
  - **Key Metrics**
    - **Total data return**
    - **End-to-end data delivery latency**
    - **Buffer size constraint**
- **Additional space-based network R&D**
  - **Distributed spacecraft missions**



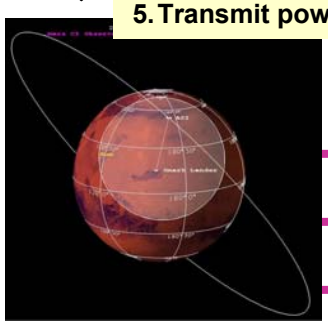




Simulation Tool Architecture

Deployment

1. Orbit ephemerides
2. Lander positions
3. EDL events
4. Antenna patterns
5. Transmit powers



SOAP

Comm. Link Engineering

1. Modulation
2. Noise
3. Data Rate(t)
4. Channel Model
5. Link Margin

Estimated received signal strength(t)

Ranges(t)

Connectivity(t)

Channel Characterization

- Multipath fading
- Atmospheric effects
- E_b/N_0 computation

Matlab

Traffic

- Telemetry Data and Command Messages Generation Processes

Data Rate(t)

Link Schedules

SNR(t) or BER(t)

Propagation delay(t)

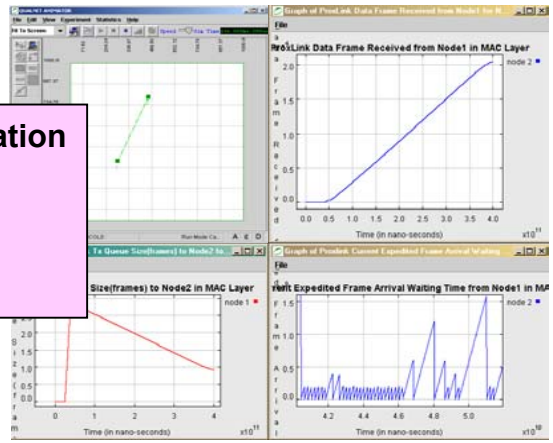
Network Simulation

- Traffic (telemetry, command)
- Proximity-1 Link Protocol
  - Hailing Process
  - Go-Back-N ARQ
  - Dynamic Data Rate
- Surface Network Model
  - Data Collection Model (topology & base stations)
  - Multi-hop Routing
  - Battery Recharge Model

Qualnet tool

Performance Characterization

- Throughput
- Buffer utilization
- Energy Use
- Latencies



Qualnet GUI

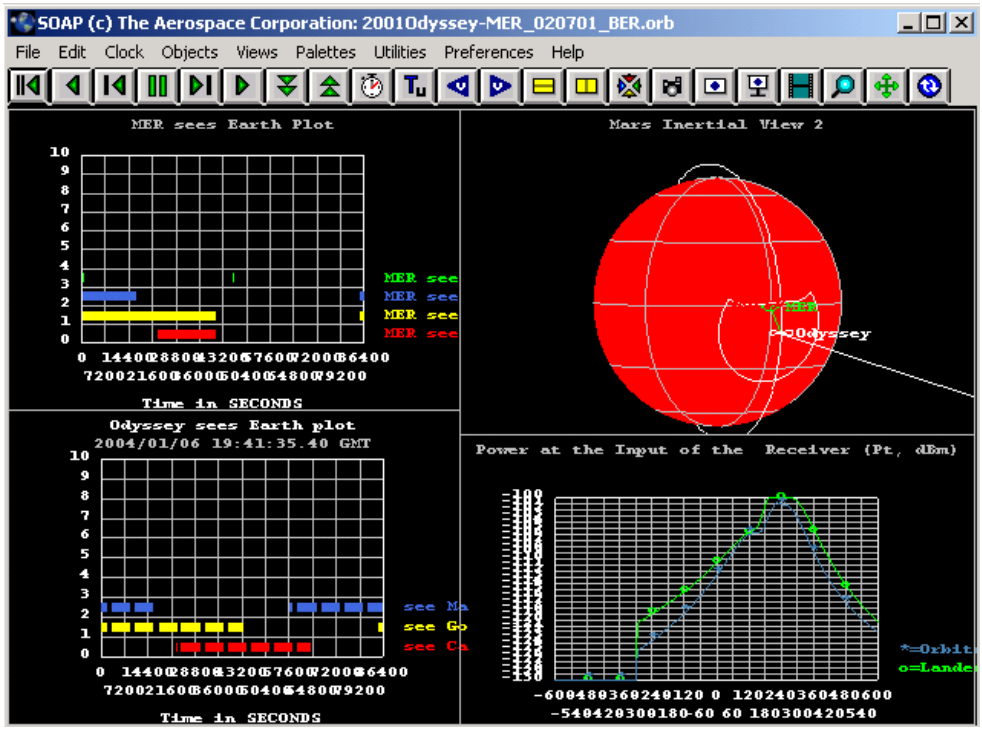
Orbital Modeling with SOAP

INPUT:

- Orbital elements
- Surface asset positions
- Telecom parameters (e.g., transmit power levels)
- Antenna patterns
- Mission scenario duration

OUTPUT:

- Received signal power profiles
- Inter-spacecraft ranges (propagation delays)
- View periods and feasible passes communications



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Characterize Channel Stochastics

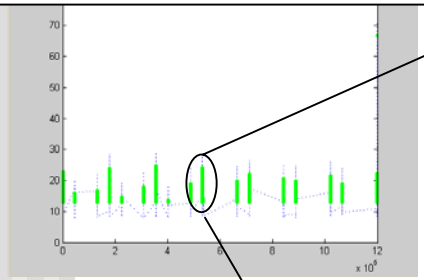
INPUT:

- SOAP data
- Hardware-dependent parameters: noise figure, noise floor
- Link engineering parameters: data rate, modulation, etc.
- Statistical parameters of phenomena affecting channel performance

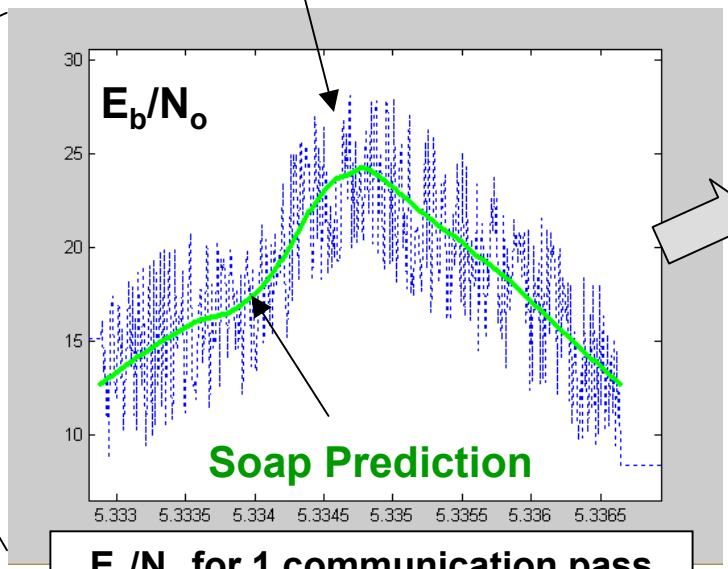
OUTPUT:

- Synthesized channel process capturing stochastic effects of multi-path fading, refraction, and other influences
- Time-varying bit-error-rate (BER) profile for each pass and data rate

E_b/N_o for 10-sol simulation

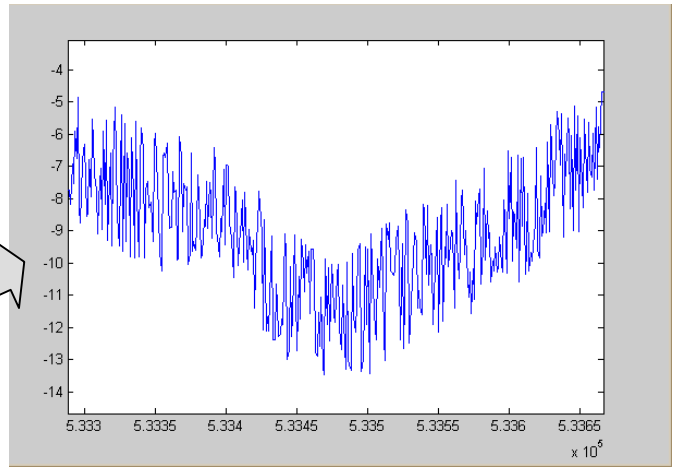


stochastic channel variations



E_b/N_o for 1 communication pass

-Log(BER) profile



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End-to-end Communications System Simulation

Input:

- Schedules for communications passes
- Bit error rates, propagation delays, and data rate profiles
- Parameters for traffic generation processes
- Protocol parameters (e.g., QoS policies)

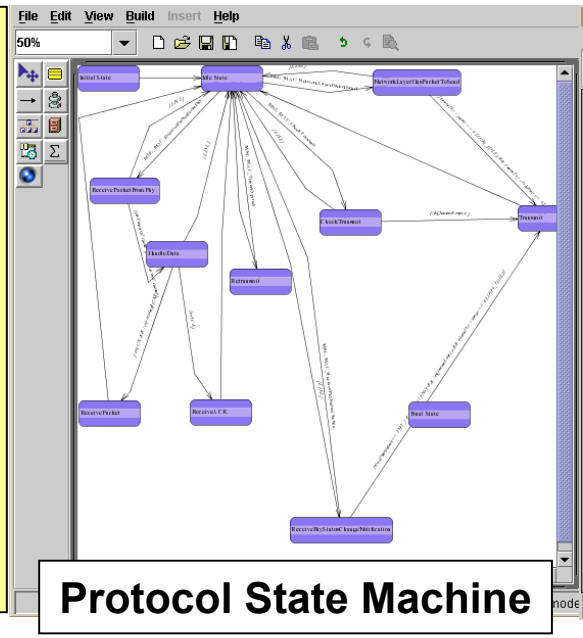
Output:

Time-dynamic processes and statistics for

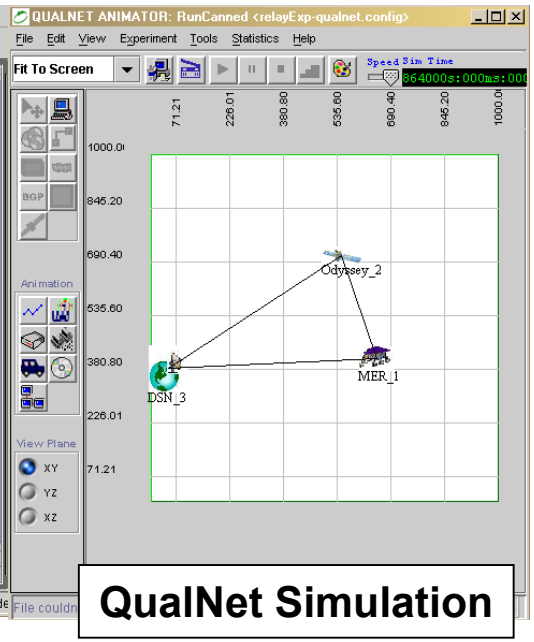
- Data transfer volumes
- Data delivery latencies
- Queue lengths

QualNet Models

- Traffic generation
- Executes behavioral models of communications protocols (including queuing disciplines)
- Statistics collection of performance metrics



Protocol State Machine



QualNet Simulation

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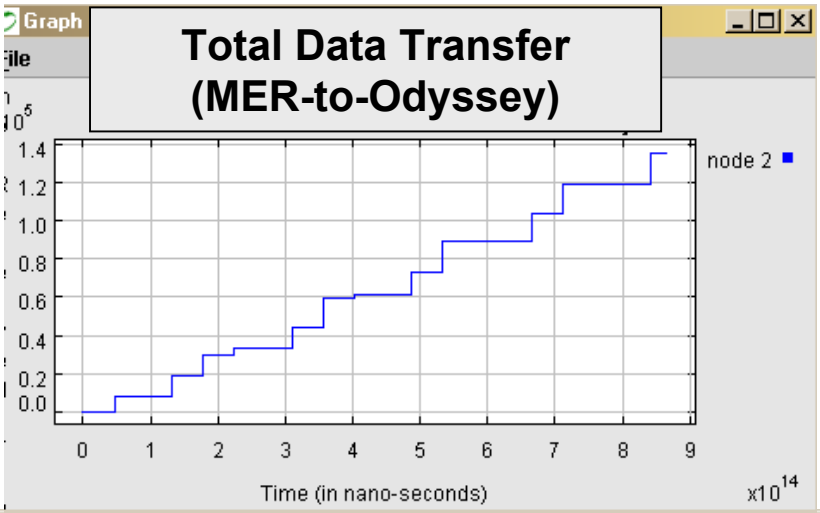
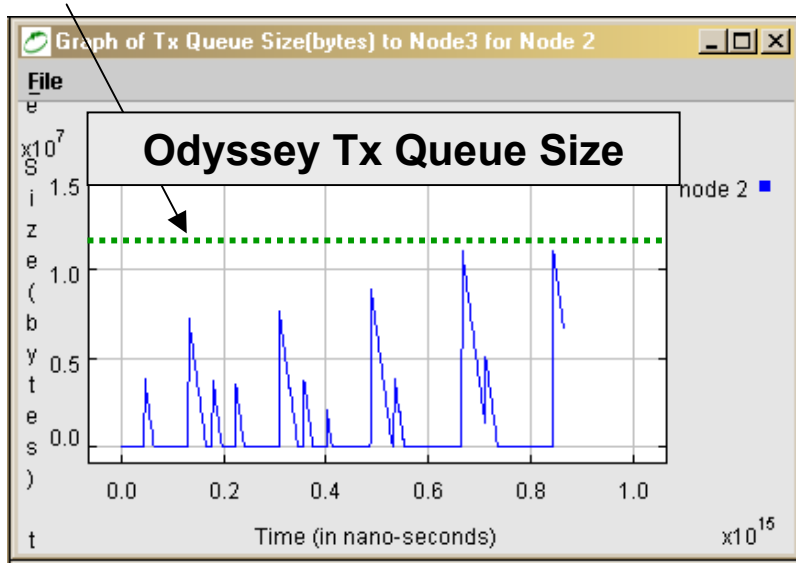
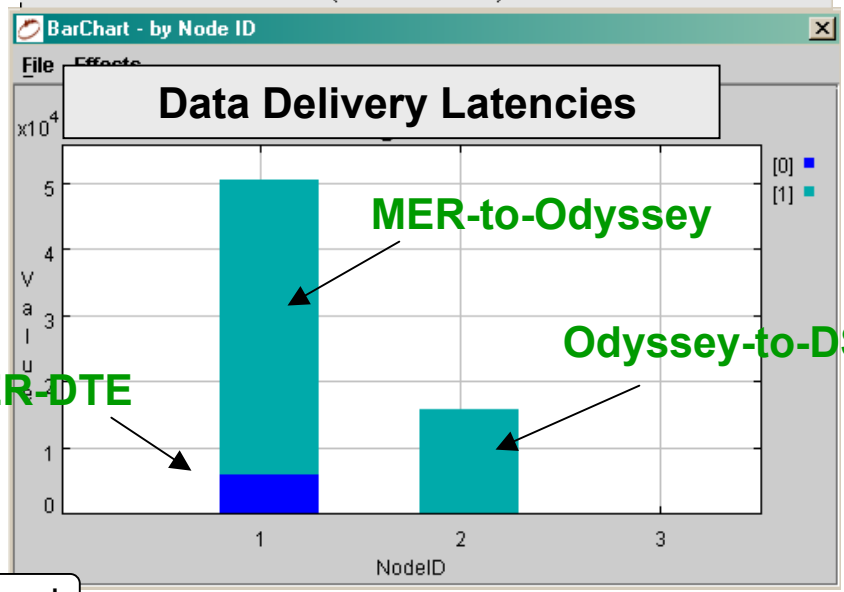
Display and Reporting of Performance Metrics

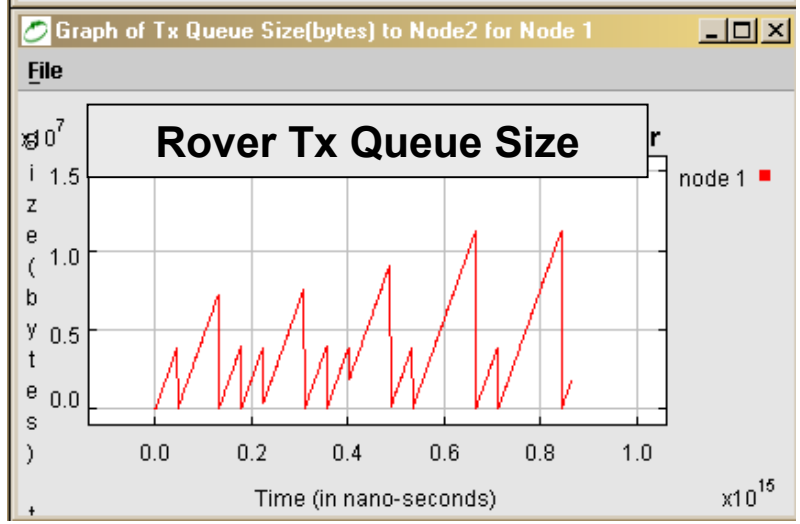
Example 10-day MER mission using Odyssey relay and DTE links

Odyssey buffer allocation for MER









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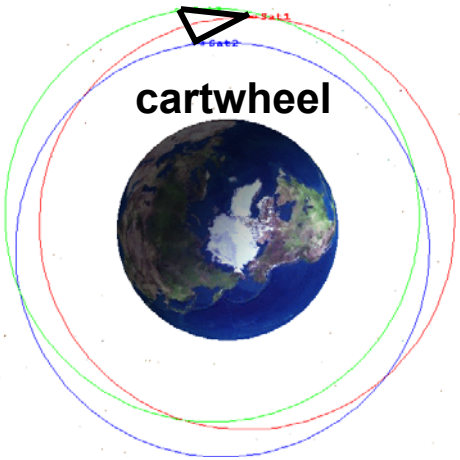
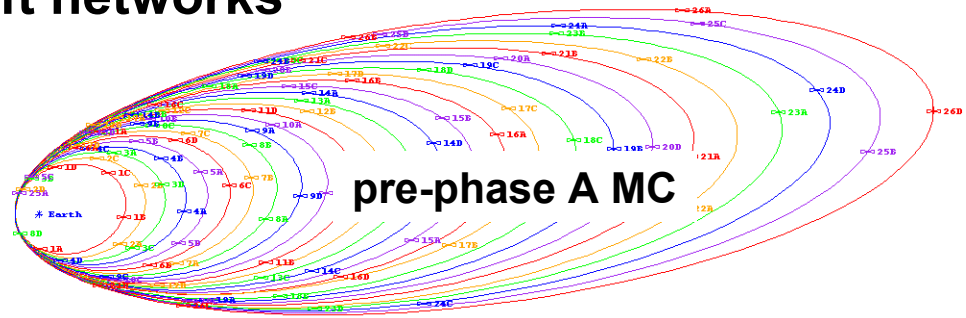
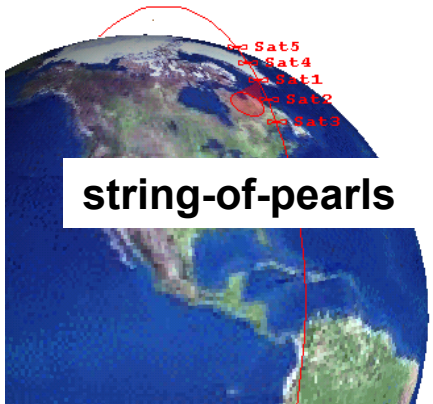
Example shown: UHF Data Rate = 512kbps; data rate at 660bits/sec

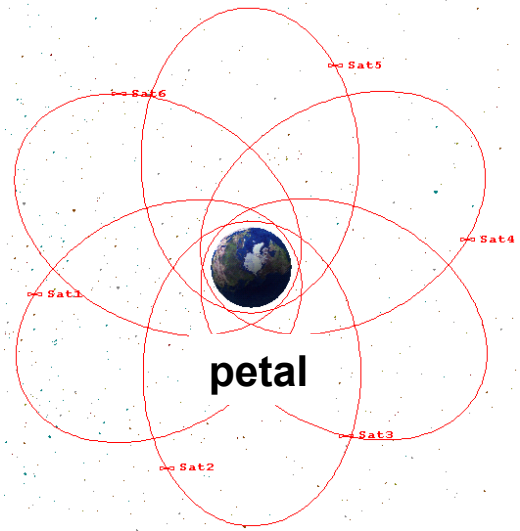
Ongoing and Future Efforts

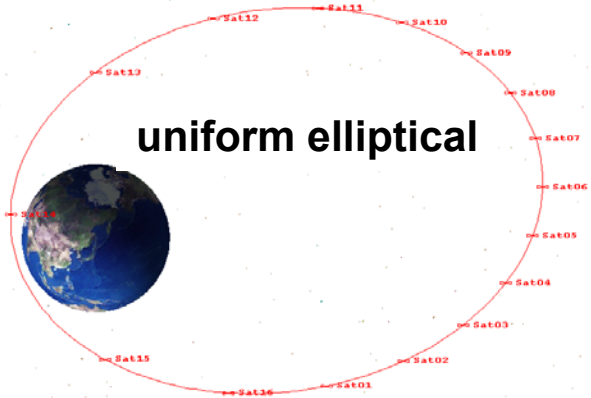
- **Simulation tool also being applied to design and validation of protocols and services for**
  - **Relay networking in the InterPlanetary Network (e.g., MSL, MTO, scouts)**
  - **Distributed spacecraft networks**











Summary

Demonstrated integrated performance tool suite (based on QualNet, SOAP & Matlab) is effective for

- **Protocol development and performance validation**
- **Aid to mission design and operation**

End-to-end relay network performance is determined using

- **Dynamics of link geometries**
- **Physical layer channel characteristics**
- **Communications traffic and protocol behaviors**